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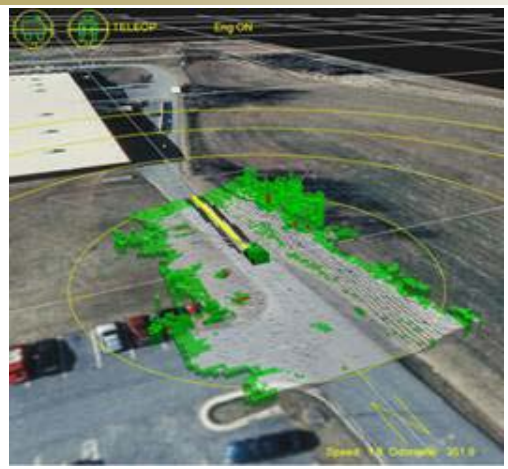
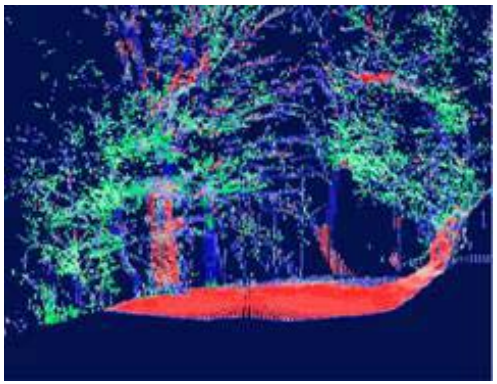


ROBOTICS COLLABORATIVE TECHNOLOGY ALLIANCE



Jon Bornstein
Collaborative Alliance Manager
Army Research Laboratory

Bill Borgia
Consortium Manager
General Dynamics Robotic Systems

Robotics CTA Overview

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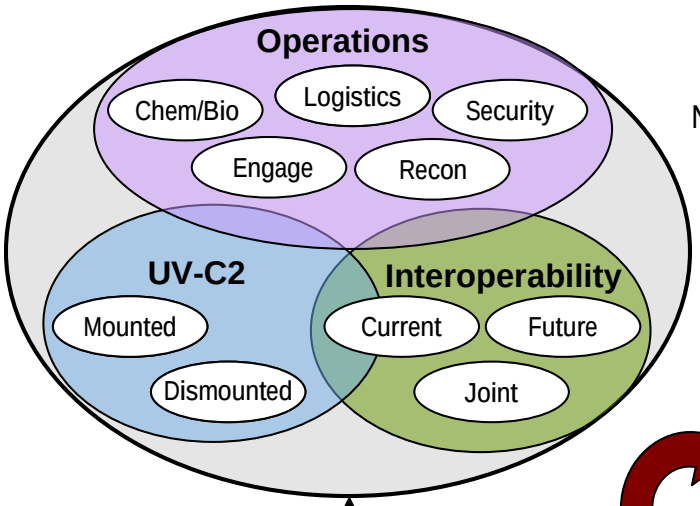
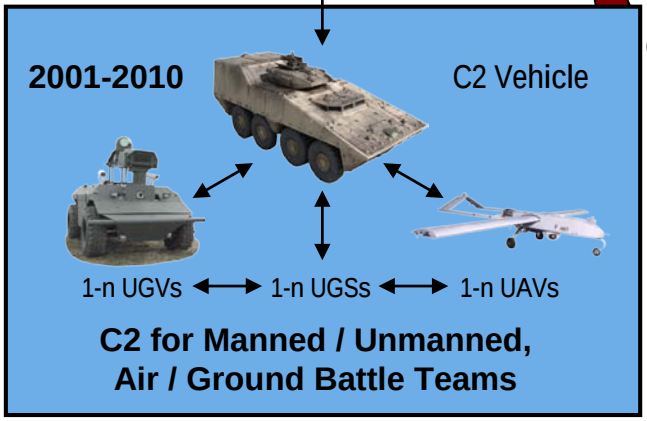
Army Needs + **Experience** = **Applied Research**



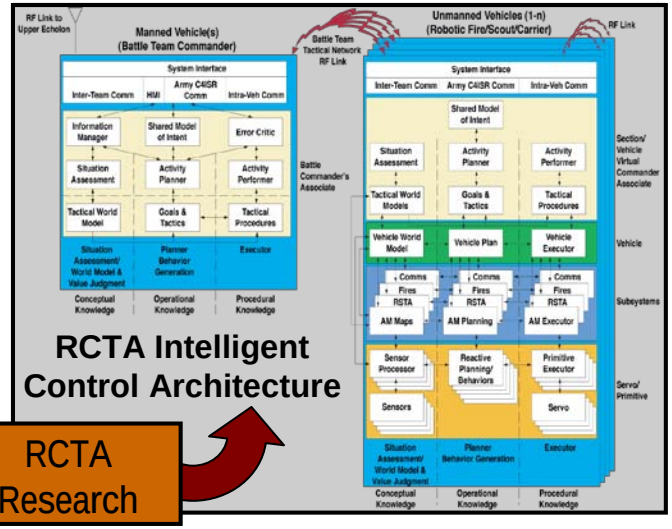


Network Centric
Battle Team Focus
Constrained Bandwidth
Info. Dissemination

User Centric
Human Performance
Trust in Automation
Workload Theory

Robot Centric
Autonomous Mobility
Tactical Behaviors
Safe Operations

Hybrid Architectures
& Reactive Behaviors



RCTA Research

Other CTAs
C&N, P&E, ADA, Sensors

Using the best resources in Government, Industry and Academia to develop and validate robotic technologies that meet current and future Army needs…

Robotics CTA Task Areas

RDECOM

CTA Inception
- Terrain Based Preplanning
- Fixed Behaviors with Fragile Performance
- Limited Replanning Under Failure Conditions
- Extensive Human Interaction Required

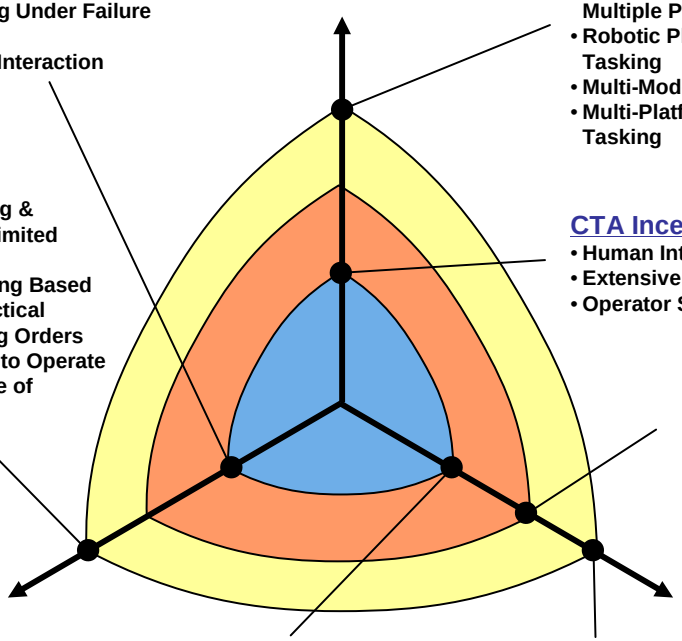
Human Machine Interface

Required
- Decision Aids for Offloading Operator
- Rapid Context Switching Between Multiple Platforms
- Robotic Platform Supervision & Tasking
- Multi-Model Input/Output
- Multi-Platform & Mixed Asset Tasking

Required
- Automatic Planning & Replanning with Limited Human Interaction
- Dynamic Replanning Based on Perception, Tactical Information, & Frag Orders
- Robust Behaviors to Operate Over a Wide Range of Situations

CTA Inception
- Human Intensive Planning
- Extensive Teleoperation Required
- Operator Saturation

CURRENT
- Program making steady progress toward required capabilities



Intelligent Control

Perception

CTA Inception
- Road Following on Well Defined Surfaces
- Slow Cross-Country Navigation in Relatively Benign Terrain
- Highly Sensitive to Environmental Effects
- Vulnerability while Platform is in Motion

Required
- All Weather, Day/Night
- Complex Environments
- Recognition of Tactical Situations
- Speed Commensurate with OPTEMPO
- Perception for Mid-Range Planning
- Understanding of Moving Agents while Platform is in Motion
- Perception to enable Vehicle Safeguarding

Technology at Program Inception

State of Current Technology

Technology Level Resulting from CTA Investment

Requires advancing the state of the art in three critical areas:

- ***Perception***
- ***Intelligent Control***
- ***Human Machine Interface***

Requires integrating research advances from all three areas using a system-level approach to provide a mechanism for:

- ***Field experimentation and research validation***
- ***User input***

Robotics CTA Members and Objectives

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Consortium Members

- General Dynamics Robotic Systems (Lead Industrial Partner)
- Carnegie Mellon University
- Applied Systems Intelligence
- Jet Propulsion Laboratory
- Alion Science & Technology
- BAE Systems
- Sarnoff Corporation
- SRI International
- Florida A&M University
- University of Maryland
- PercepTek
- Robotic Research
- Signal Systems Corp
- Howard University
- NC A&T University
- University of Pennsylvania
- Skeyes Unlimited

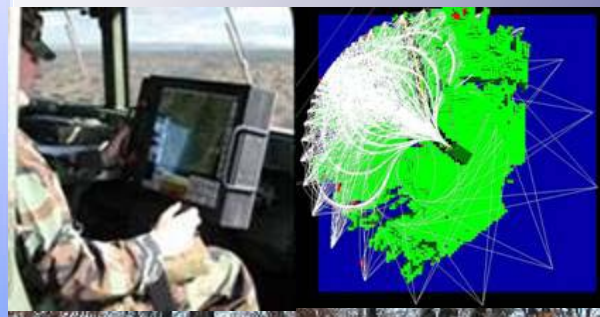
Objectives

Make the research investments that support the Army's robotic system development goals:

- *Develop perception technologies that allow robotic vehicles to sense and understand their environment;*
- *Develop intelligent control technologies and architectures enabling robotic systems to autonomously plan, execute, and monitor operational tasks undertaken in complex, tactical environments;*
- *Develop human-machine interfaces that allow soldiers to effectively task robotic systems and minimize operator workload.*

Technical Areas

- Advanced Perception
- Intelligent Control & Behavior Development
- Human / Machine Interfaces



Robotics CTA – Member Distribution

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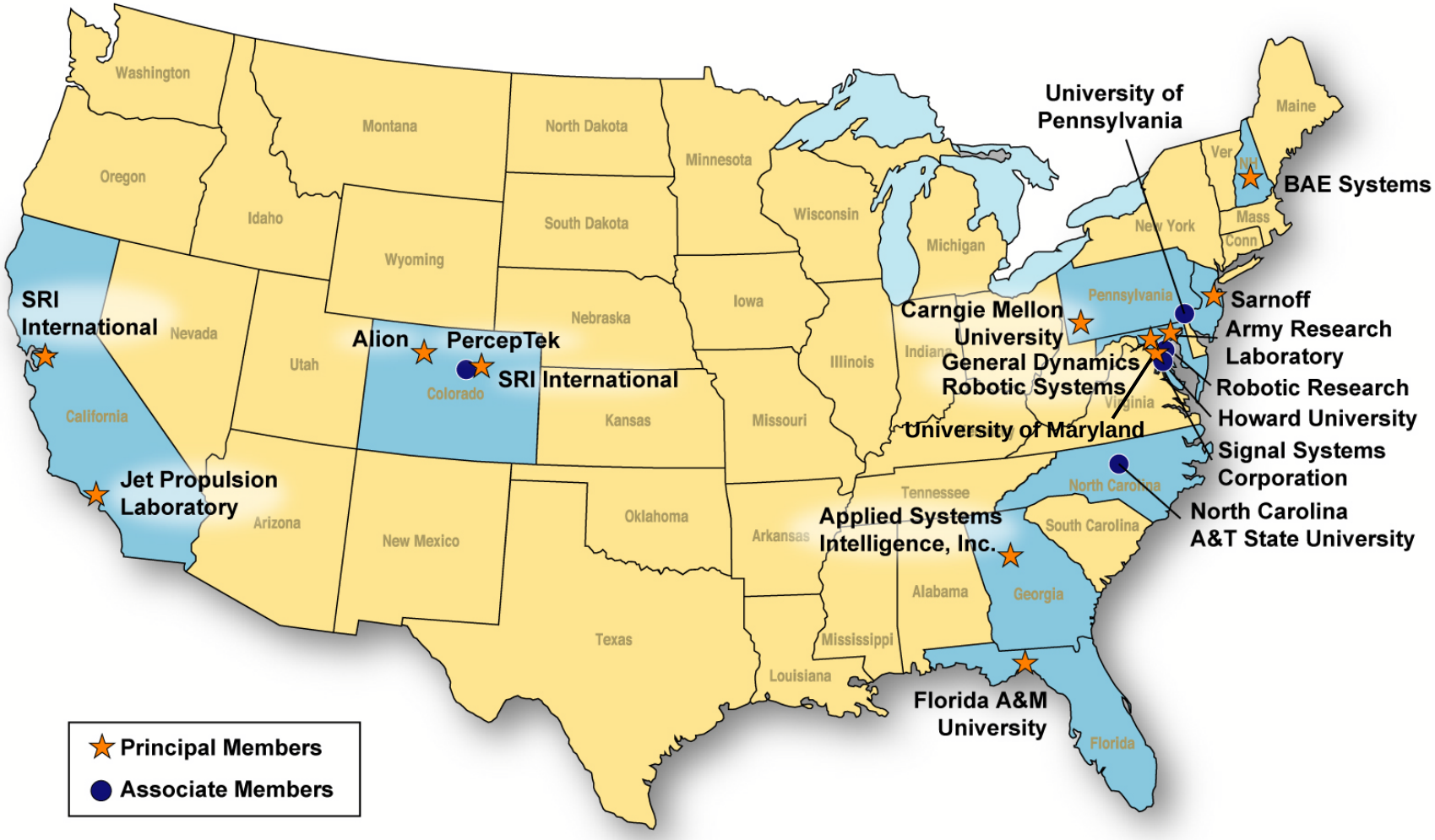
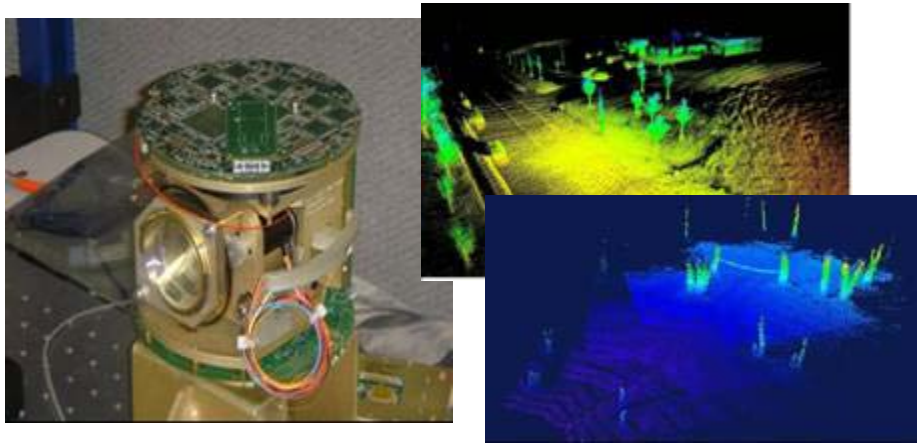


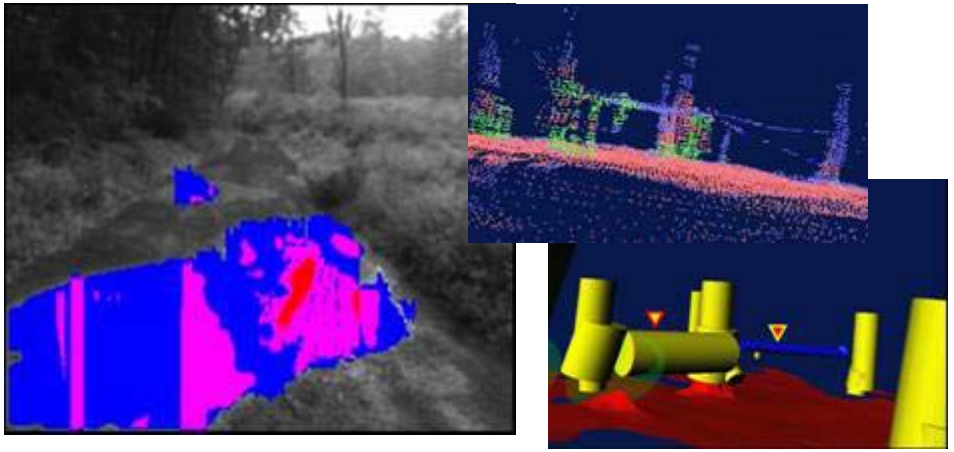
Advances in Sensors and Perception

RDECOM

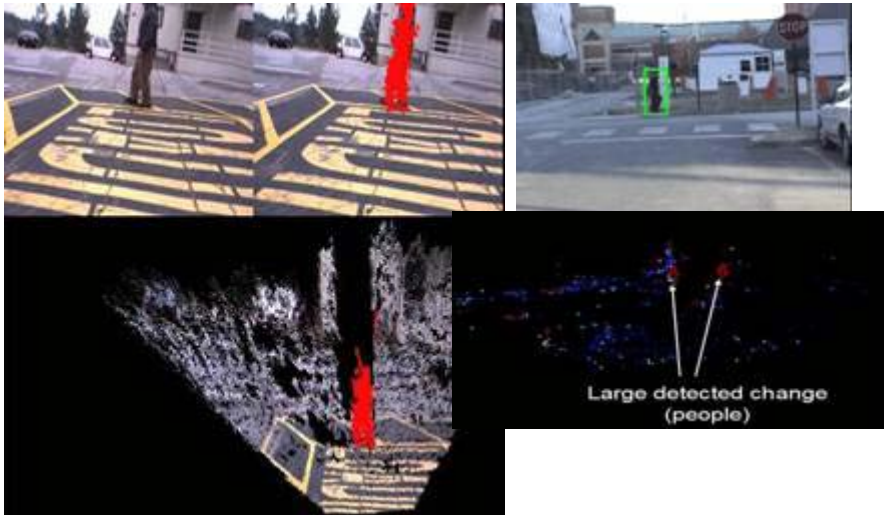
LADAR Development & Processing Algorithms



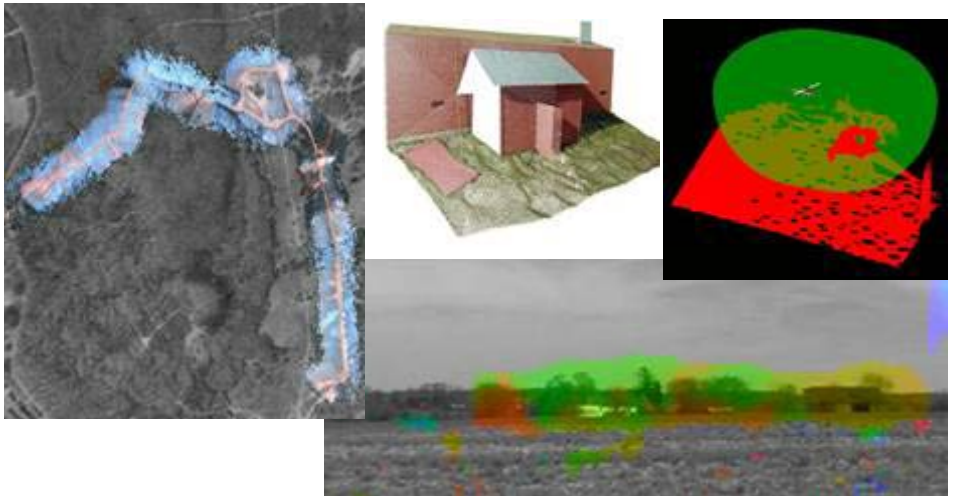
Terrain Classification



Moving Agent Understanding



Air / Ground & Mid-Range Sensing

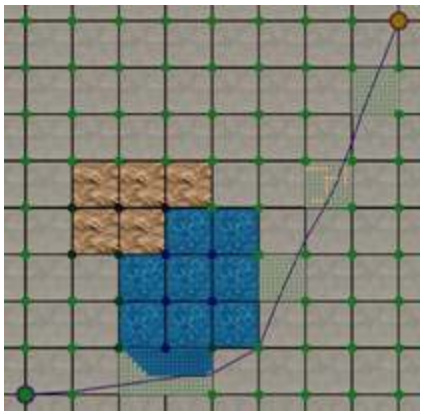


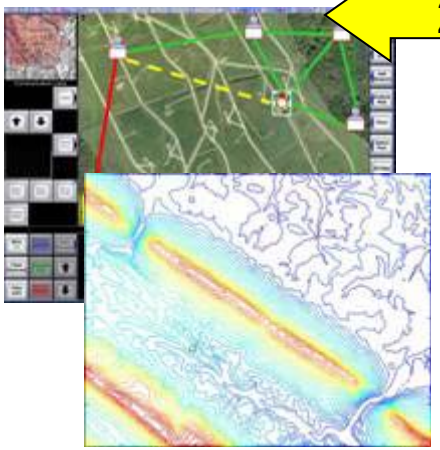
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Advances in Intelligent Control

RDECOM

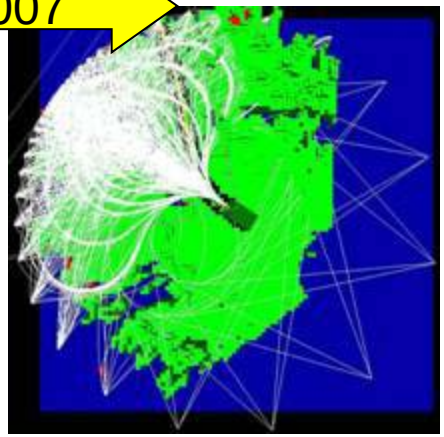
Global Planning for Robotic Vehicles

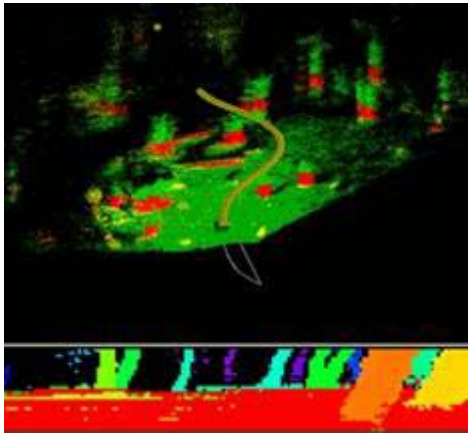




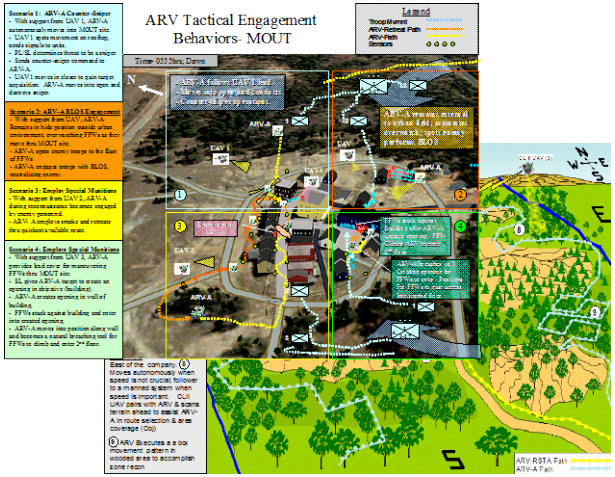
2007

Local Planning for Robotic Vehicles

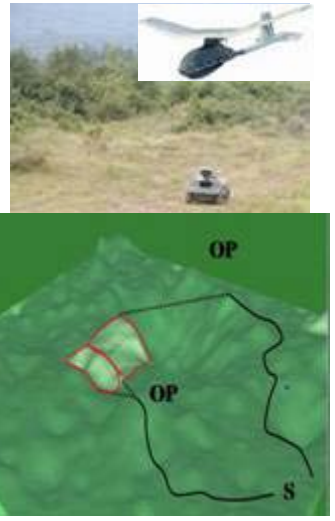




Tactical Behaviors



Collaborative Operations



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Advances in Human Machine Interface

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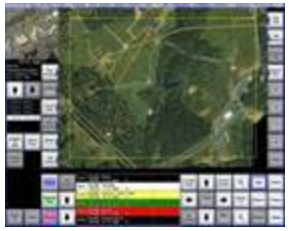
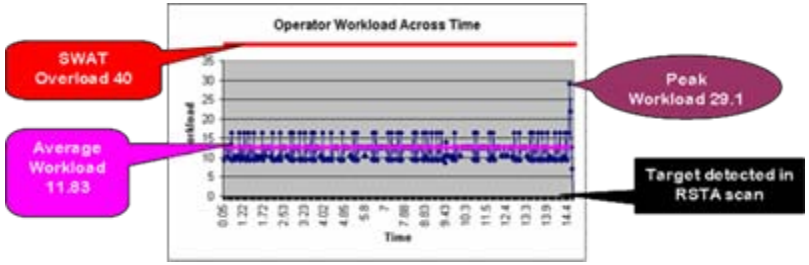
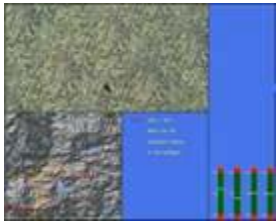
Scalable Human Machine Interfaces

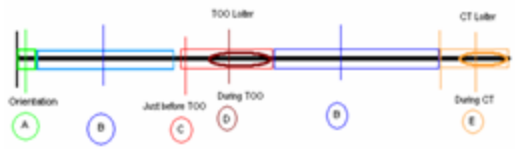


Multi-Modal Input

Workload / Trust in Automation



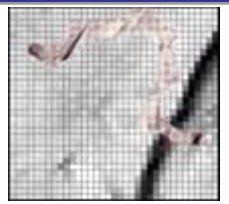
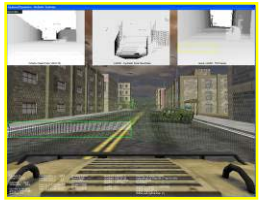
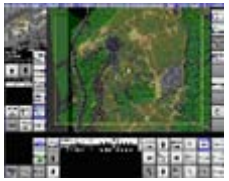
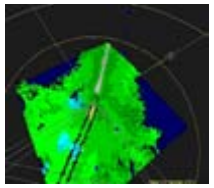




HMI Interface Extensions

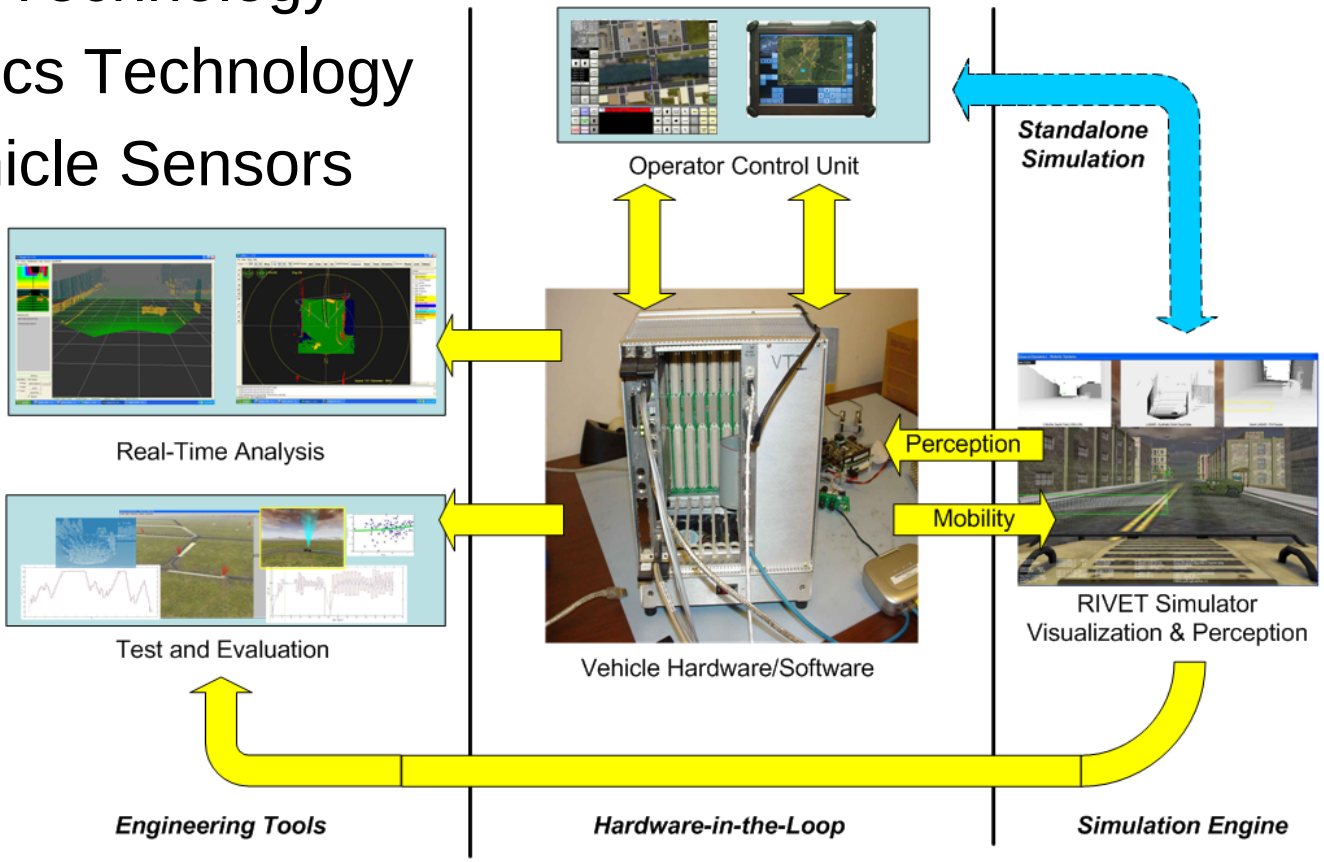
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Stages of Experimentation and Integration

Proof of Concept Testing with COTS Hardware Researchers test proof of concept in their own labs with commercial off-the-shelf (COTS) hardware. The image at right is from the Carnegie Mellon Robotics Institute Laboratory.		
Perception and Autonomous Navigation Testing with GDRS Standardized Test Facilities GDRS facilities are used to test perception and autonomous navigation tasks. Data is analyzed against the ground truth of known obstacles. ARL and NIST design quantitative experiments.		
Simulation Testing with RCTA SIL The RCTA Systems Integration Lab (SIL) at GDRS provides a hardware-in-the loop simulation testbed for Advanced Perception, Intelligent Control Architecture (ICA) and Human Machine Interface (HMI) technologies.		
Integration and Testing in Realistic Environments New technology is integrated and tested on the Demo III XUV and commercial vehicles in various terrains including rolling and forested terrain, as well as a MOUT environment at Fort Indiantown Gap.		

Hardware-in-the-Loop Simulation

- Capability Developed in FY 2007
- Leverages Visualization Technology from COTS Gaming Technology
- Exploits Graphics Technology to Emulate Vehicle Sensors

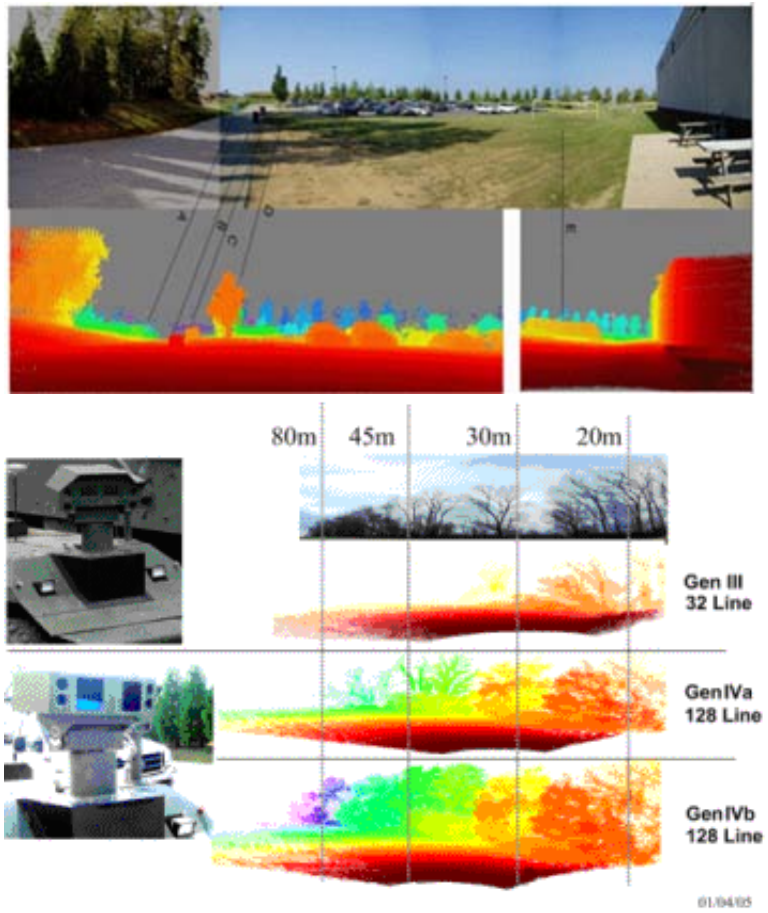


RCTA FY07 Metrics

Robotics Collaborative Technology Alliance Metrics FY07		
Metric	**FY02-06**	**FY07**
Scholarly Papers	182	26
Invention Disclosures	2	2
Patent Applications Filed	5	1
Masters Degrees Awarded	12	9
Ph.Ds. Awarded	10	4
Graduate Students Supported	88	14

RCTA Transitions to FCS ANS

- Provided the technical foundation for FCS-ANS and the demonstration in 2003 that was instrumental in funding FCS unmanned ground systems
  - Field-tested LADAR hardware
  - LADAR processing algorithms for obstacle detection, classification algorithms for obstacle detection, and terrain classification
  - Engineering visualization tools for LADAR and vehicle planner development
  - Field-tested robotic testbed platforms (with interfaces to navigation sensors), capable of data collection and archiving in realistic tactical environments
  - LADAR optics, TX/RX electronics and processing firmware (FFT, multi-pulse, ranging, etc.)
  - Passive perception system algorithms; stereo correlator, rectification and pyramid algorithms



RCTA Transitions to TARDEC VTI Advanced Development Programs

- Hardware and software perception sensors
- Sensor processing algorithms, including pedestrian detection algorithms
- Vehicle planners
- Planning algorithms via Terrain Reasoner
- Selected tactical and cooperative behavior algorithms
- Perception technologies from the 3500-pound XUV testbed to the 18-ton Stryker vehicle
- SMI related components

RCTA Transitions to PM-FPS MDARS

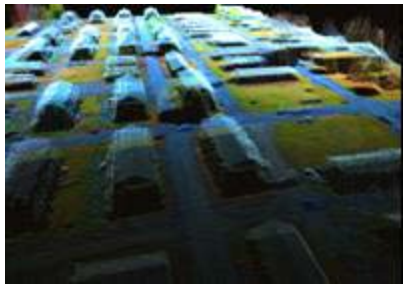
RDECOM

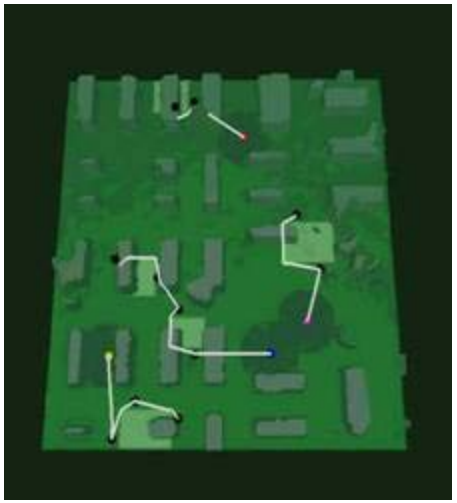
- Perception Sensors (LADAR and EO/IR)
- Sensor processing algorithms
- Vehicle planners and OA Planning algorithms
- LADAR optics and TX/RX electronics
- LADAR processing firmware (FFT, multi-pulse, ranging, etc.)
- Acadia Vision Processor

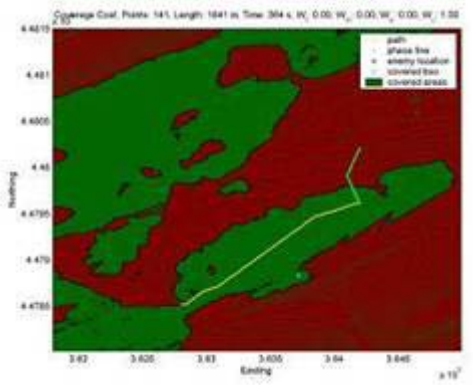
RCTA Transitions to AATD UACO

RDECOM

- UGV Perception Sensors and Demonstration Platforms
- UGV and LADAR Sensor Processing Algorithms
- Vehicle planners and OA planning algorithms
- Market-Based Collaborative Tasking Algorithms
- SMI Interface, Decision Support System, and Terrain Reasoner
- Air / Ground Cooperative C2
- Test and Demo Facilities





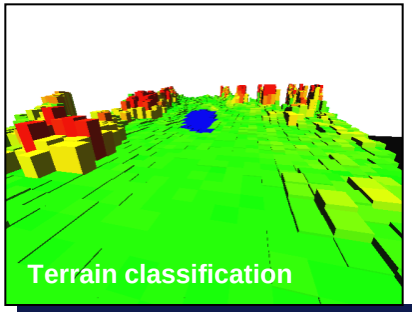


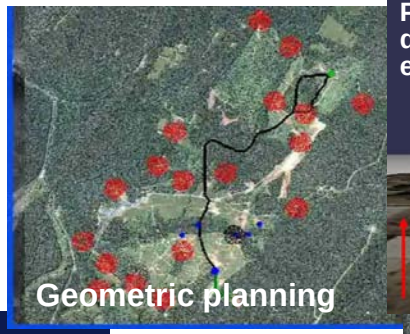
Entered Low Rate Initial Production in December 2007

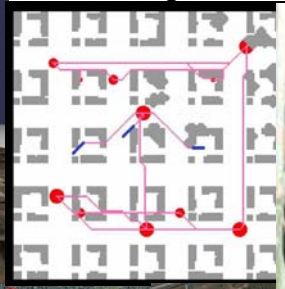
- **Perception Sensors (LADAR and EO/IR)**
- **Sensor processing algorithms**
- **Vehicle planners and OA planning algorithms**
- **LADAR optics and TX/RX electronics**
- **LADAR processing firmware (FFT, multi-pulse, ranging, etc.)**
- **Acadia Vision Processor**

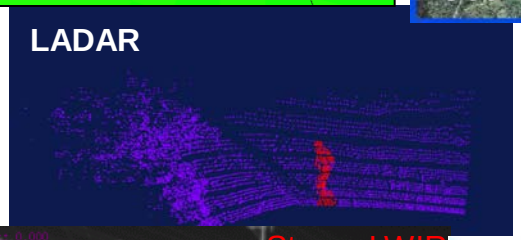
Robotics CTA

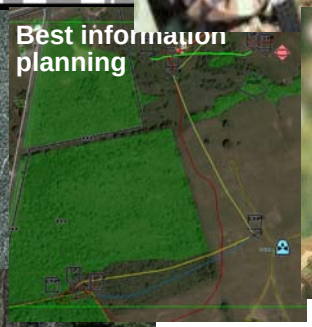
RDECOM

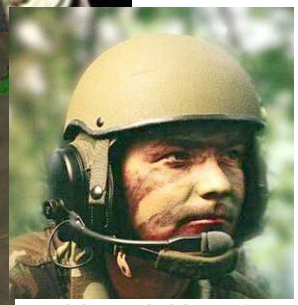


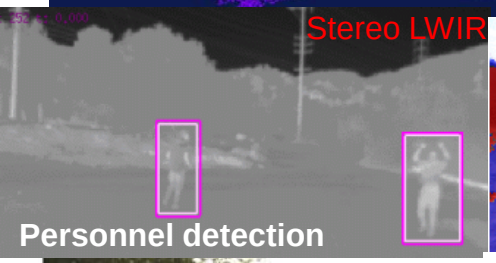


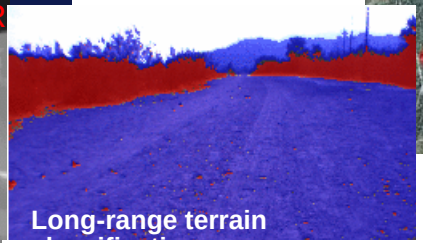


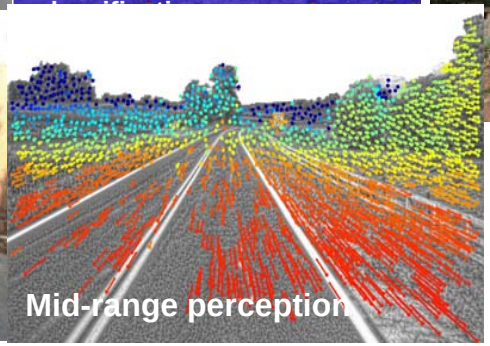












Providing key technology for future Army unmanned systems

TECHNOLOGY DRIVEN. **WARFIGHTER FOCUSED.**